S.V. Akkelin
(BITP, Kiev)

SIMPLE ESTIMATES OF NON-FEMTOSCOPY CORRELATIONS IN p + p COLLISIONS

in collaboration with Yu.M. Sinyukov

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INTRODUCTION

Identical pion correlation functions

The correlation function is defined as

$$C(p_1, p_2) = \frac{P(p_1, p_2)}{P(p_1)P(p_2)}$$

where $P(p_1, p_2)$ is the probability of observing two particles with momenta p_1, p_2 while $P(p_1)$ and $P(p_2)$ denote single-particle probabilities

Experimentally, the two-particle distribution function is defined as ratio of a distribution of the pairs from the same event and pairs of particles from the different events

$$C_{\mathbf{p}}(\mathbf{q}) = \frac{A_{\mathbf{p}}(\mathbf{q})}{B_{\mathbf{p}}(\mathbf{q})}$$

where $p = (p_1 + p_2)/2$ and $q = p_2 - p_1$

Two-pion Bose-Einstein correlations in heavy ion collisions

In heavy ion collisions all of the correlations between identical pions at low relative momentum are due to quantum statistics and final-state interactions ("femtoscopic effects"):

$$C(p,q) = C_F(p,q)$$

and in the simplest case (and without FSI) the Bose-Einstein correlations can be parameterized by a Gaussian,

$$C_F(|\mathbf{p}|, q_{inv}) = 1 + \lambda \exp\left(-R_{inv}^2 q_{inv}^2\right)$$

with λ describing the correlation strength, R_{inv} being the Gaussian one dimensional "HBT radius", and

$$q_{inv} = \sqrt{(\mathbf{p}_2 - \mathbf{p}_1)^2 - (E_2 - E_1)^2}$$

is, for identical mass particles, equal to the modulus of the momentum difference in the pair rest frame.

Two-pion Bose-Einstein correlations in p+p collisions

In elementary particle collisions additional (long-range) correlations have been observed ("non-femtoscopic effects") like those arising from jet/string fragmentation and/or from energy and momentum conservation. Then

$$C(p,q) = C_F(|\mathbf{p}|, q_{inv}) C_{NF}(|\mathbf{p}|, q_{inv})$$

where "non-femtoscopic effects" are parameterized in term of function

$$C_{NF}(|\mathbf{p}|, q_{inv})$$

that can be fitted as, e.g., 2^{nd} order polynomial

$$C_{NF}(|\mathbf{p}|, q_{inv}) = a + bq_{inv} + cq_{inv}^2$$

Non-femtoscopic effects contribute noticeably to the correlation function!

Non-femtoscopic correlations (baseline)

STAR (RHIC):

- phenomenological parameterizations of C_{NF}
- EMCIC (energy and momentum conservation induced correlations) parameterization of C_{NF} (Z. Chajecki, M. Lisa)

ALICE (LHC):

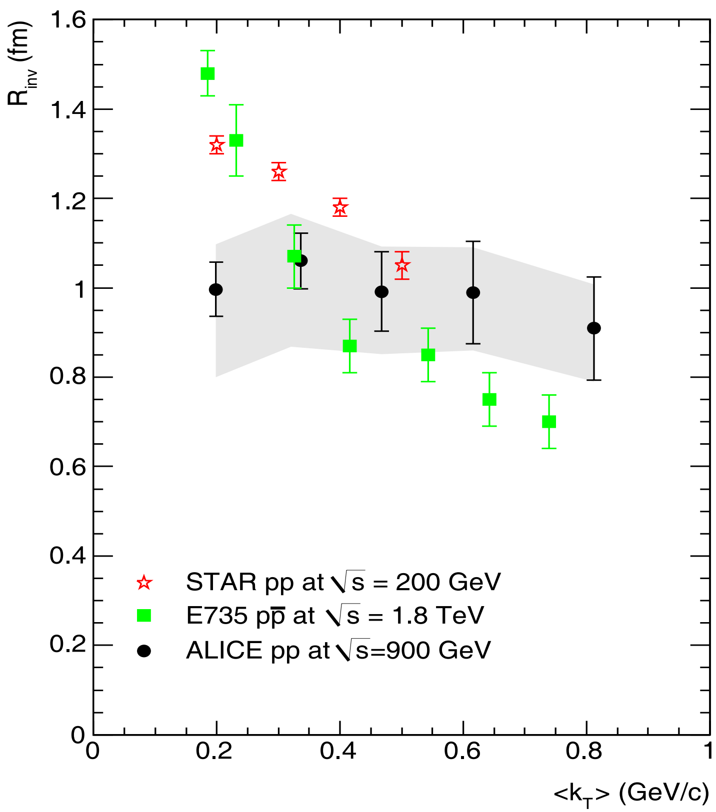
- C_{NF} from a Monte-Carlo simulations with the PHOJET and PYTHIA event generators (soft and hard processes, energy and momentum conservation, without QS)

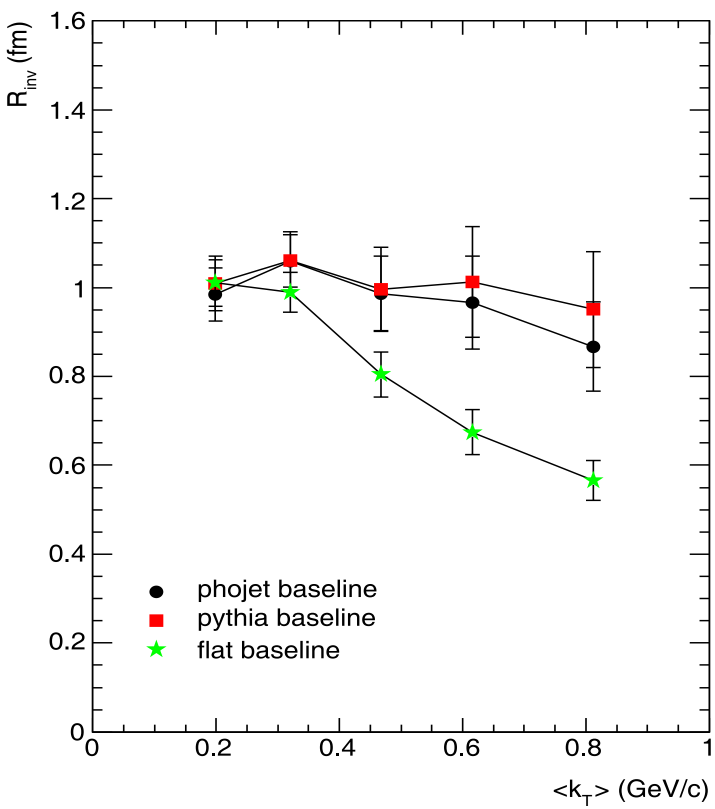
ALICE and STAR : flat baseline $(C_{NF} = 1)$

Two-pion Bose-Einstein correlations in p+p collisions

at $\sqrt{s} = 900$ GeV (LHC, ALICE Collaboration) and
at $\sqrt{s} = 200$ GeV (RHIC, STAR Collaboration)

HYDRO flow? Transverse momentum behavior of HBT radii depends on correlation baseline assumption!





RESULTS

Can the non-femtoscopic correlations from PHOJET and PYTHIA be explained by the energy-momentum conservation induced correlations only?

EMCIC:

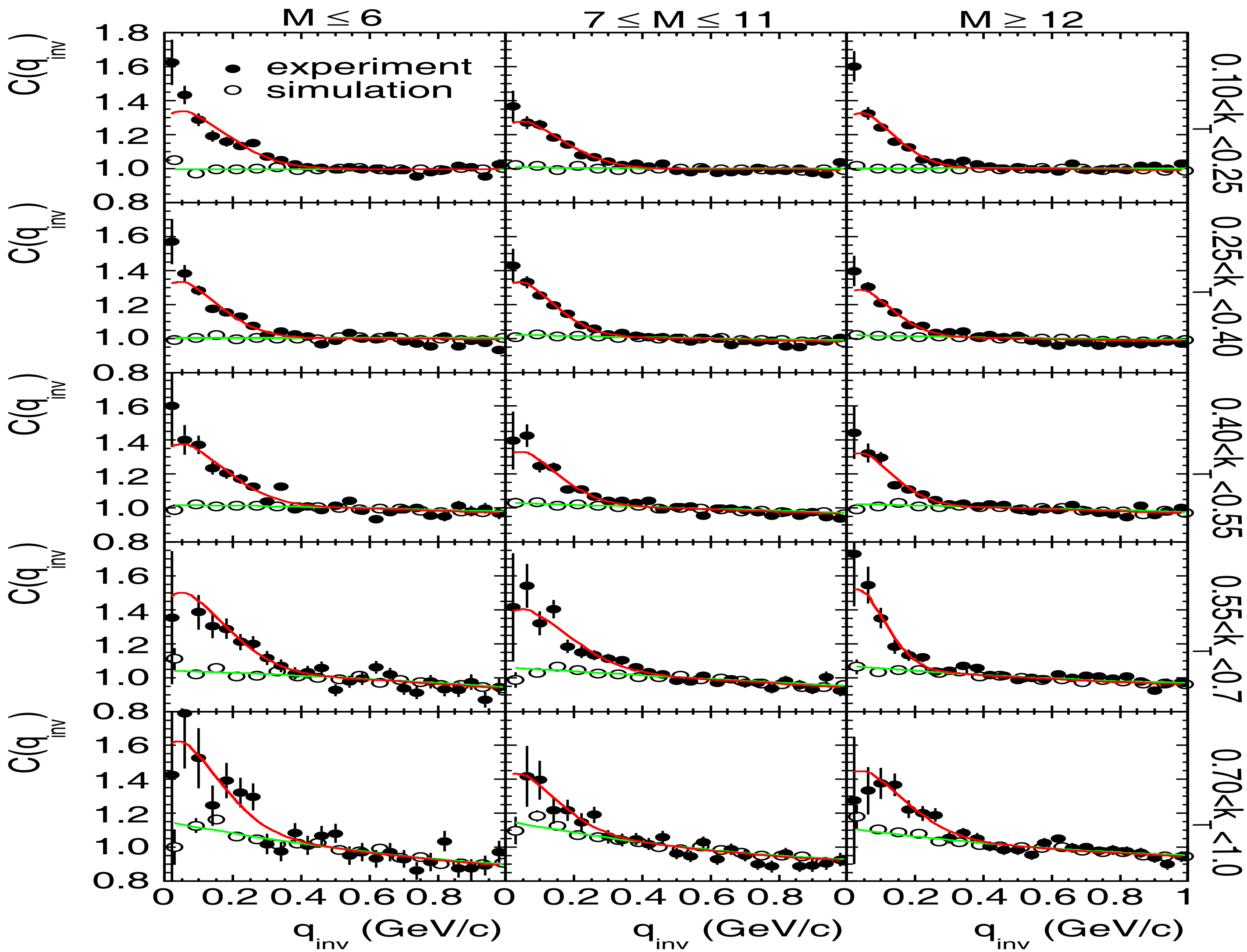
$$C_{NF}(p,q) = 1 - \frac{1}{N}\left(2\frac{\vec{p}_{1,T}\cdot\vec{p}_{2,T}}{\langle p_T^2\rangle} + \frac{p_{1,z}\cdot p_{2,z}}{\langle p_z^2\rangle} + \frac{(E_1-\langle E\rangle)(E_2-\langle E\rangle)}{\langle E^2\rangle-\langle E\rangle^2}\right)$$

$$\mathbf{p}_1 = \mathbf{p} - \mathbf{q}/2$$

$$\mathbf{p}_2 = \mathbf{p} + \mathbf{q}/2$$

$C_{NF}(p,q)$ increases with q

Non-femtoscopic correlations from PHOJET (ALICE paper)



C_{NF} from PHOJET – conservation laws and jet-like induced correlations ?

Non-femtoscopic correlation function (model)

$$C_{NF}(p,q) = \frac{\frac{d^2\sigma}{\sigma dp_1 dp_2}}{\frac{d\sigma}{\sigma dp_1}\frac{d\sigma}{\sigma dp_2}}$$

Single-particle cross-section from N-particle amplitude:

$$E_1 \frac{d\sigma}{dp_1} = K \int \frac{dp_2}{E_2} ... \frac{dp_N}{E_N} \delta^{(3)}(\mathbf{p}_1 + \mathbf{p}_2 + ... \mathbf{p}_N) |M_N(p_1, p_2, ..., p_N)|^2$$

momentum conservation
in N-particle system

$$\rightarrow \quad \delta^{(3)}(\mathbf{p}_1 + \mathbf{p}_2 + ... \mathbf{p}_N)$$

$$\delta^{(3)}(\mathbf{p}_1 + \mathbf{p}_2 + ... \mathbf{p}_N) = \frac{1}{(2\pi)^3} \int dr \exp\left(i\mathbf{r}\mathbf{p}_1 + \mathbf{p}_2 + ... \mathbf{p}_N\right)$$

$$E_1 \frac{d\sigma}{dp_1} = \frac{K}{(2\pi)^3} \int dr \exp\left(i\mathbf{r}\mathbf{p}_1\right) G(\mathbf{p}_1, \mathbf{r})$$

$$G(\mathbf{p}_1, \mathbf{r}) = \int \frac{dp_2}{E_2} ... \frac{dp_N}{E_N} \exp\left(i\mathbf{r}(\mathbf{p}_2 + ... \mathbf{p}_N)\right) |M_N(p_1, p_2, ..., p_N)|^2$$

Non-femtoscopic correlations
as mini-jet and momentum conservation induced correlations

(EMCIC): correlations arise from conservation laws only

$$|M_N(p_1,p_2,...,p_N)|^2 = f(p_1)f(p_2)...f(p_{N-1})f(p_N)$$

correlations arise from momentum conservation and low p_T jet-like structure (mini-jets):

$$|M_N(p_1,p_2,...,p_N)|^2 = f(p_1)f(p_2)C_{mjet}(p_1,p_2)...f(p_{N-1})f(p_N)C_{mjet}(p_{N-1},p_N)$$

+ another (2, 3, …) cluster combinations of particles

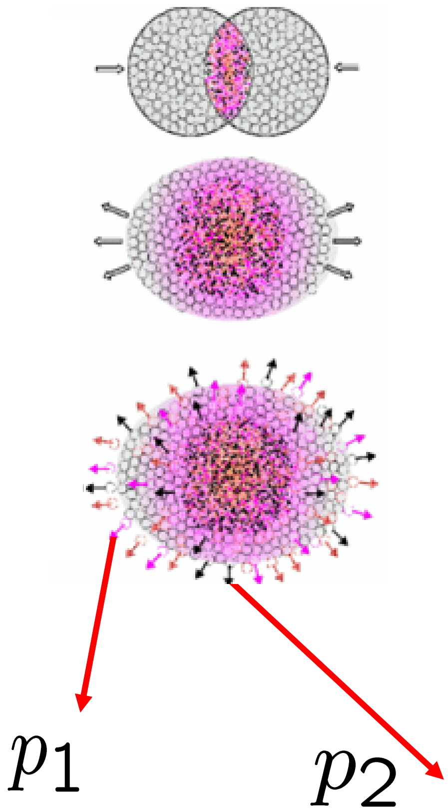
Simplifying assumptions:

1) one mini-jet → two particles

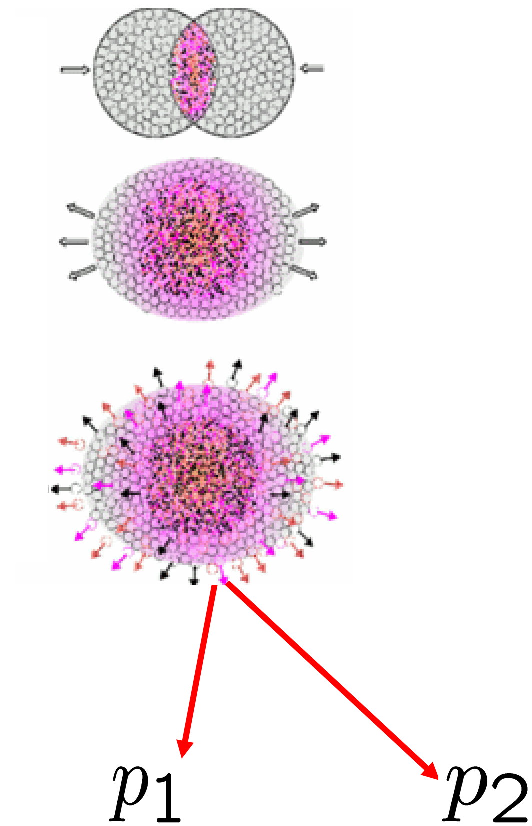
2) $C_{mjet}(p_i,p_j)$ has peak for same-side configuration and near velocities (similar to coalescence models)

Two-particle production:

from different mini-jets



from the same mini-jet



Second term can contribute noticeably for small systems!

$$\frac{d^2\sigma}{dp_1 dp_2} = \frac{d^2\sigma_{mjet-2}}{dp_1 dp_2} + \frac{2}{N-2}\frac{d^2\sigma_{mjet-1}}{dp_1 dp_2}$$

Simple model for non-femtoscopic correlations

$$f(p_i) = E_i \exp\left(-\frac{\mathbf{p}_{i,T}^2}{T_T^2}\right) \exp\left(-\frac{\mathbf{p}_{i,L}^2}{T_L^2}\right)$$

$$C_{mjet}(p_i, p_j) = \exp\left(-\frac{(\mathbf{p}_i - \mathbf{p}_j)^2}{\alpha^2}\right)$$

$$q_{inv} = \sqrt{(\mathbf{p}_2 - \mathbf{p}_1)^2 - (E_2 - E_1)^2}$$

$$\mathbf{p}_1 = \mathbf{p} - \mathbf{q}/2, \qquad \mathbf{p}_2 = \mathbf{p} + \mathbf{q}/2$$

$$q_{inv}^2 \approx \mathbf{q}_T^2 \left(\frac{m^2 + \mathbf{p}_T^2 \sin^2\phi}{m^2 + \mathbf{p}_T^2}\right), \qquad \mathbf{p}_T \mathbf{q}_T = |\mathbf{p}_T||\mathbf{q}_T| \cos\phi$$

$$T_L \gg T_T, \; p_{1,L} = p_{2,L} = 0$$

Non-femtoscopic correlations

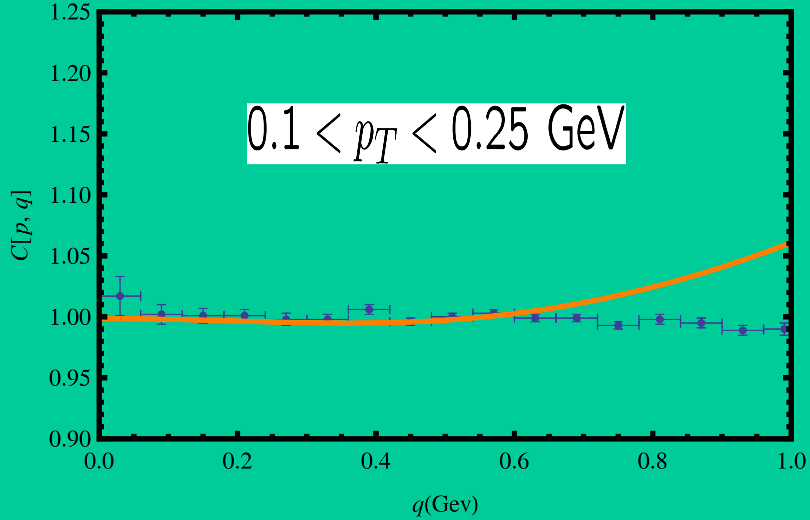
$$C_{NF}(|\mathbf{p}_T|, q_{inv}) = \frac{\int_0^{2\pi} d\phi \left(\frac{d^2\sigma_{mjet-2}}{\sigma dp_1 dp_2} + \frac{2}{N-2} \frac{d^2\sigma_{mjet-1}}{\sigma dp_1 dp_2} \right)}{\int_0^{2\pi} d\phi \left(\frac{d\sigma_{mjet}}{\sigma dp_1} \frac{d\sigma_{mjet}}{\sigma dp_2} \right)}$$

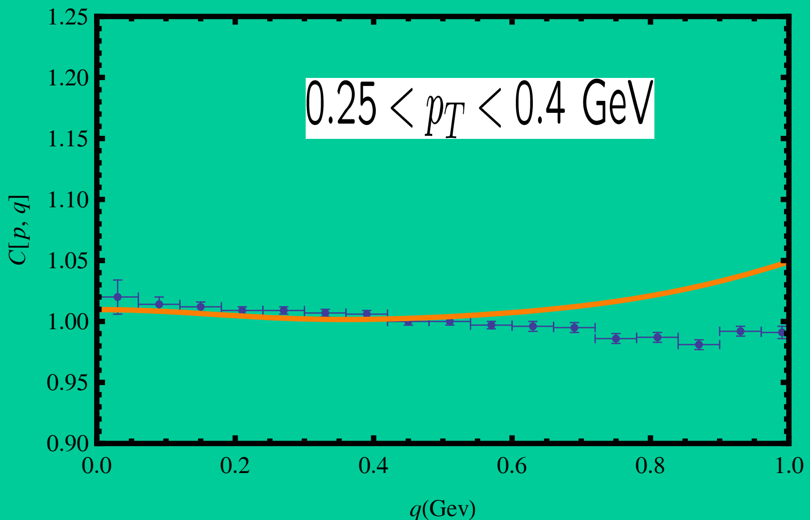
$$C_{NF}(|\mathbf{p}_T|, q_{inv}) = C_{NF}^{mjet-2}(|\mathbf{p}_T|, q_{inv}) + C_{NF}^{mjet-1}(|\mathbf{p}_T|, q_{inv})$$

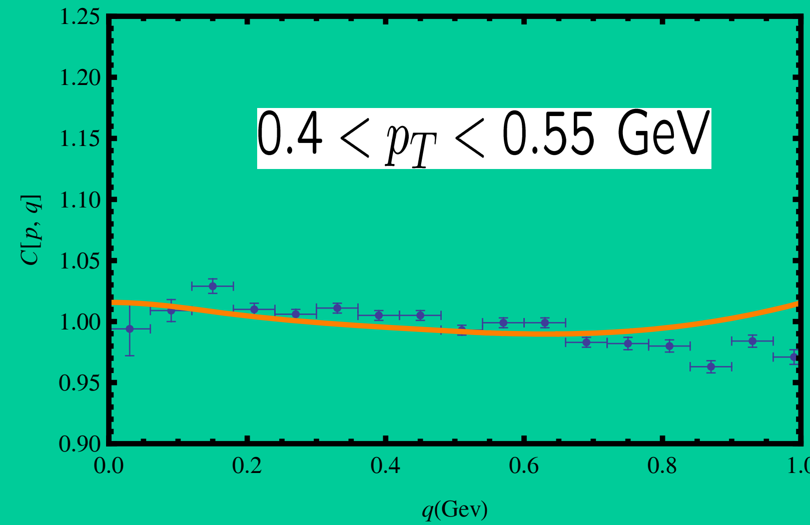
Single-particle spectrum

$$E_1 \frac{d\sigma}{dp_1} \sim \exp\left(-\frac{\mathbf{p}_{1,T}^2}{T_T^{*2}(T_T, a, N)} \right)$$

$N = 17$, $T_T = \alpha = 0.75$ GeV,
then $\langle p_T \rangle \approx 0.67$ GeV

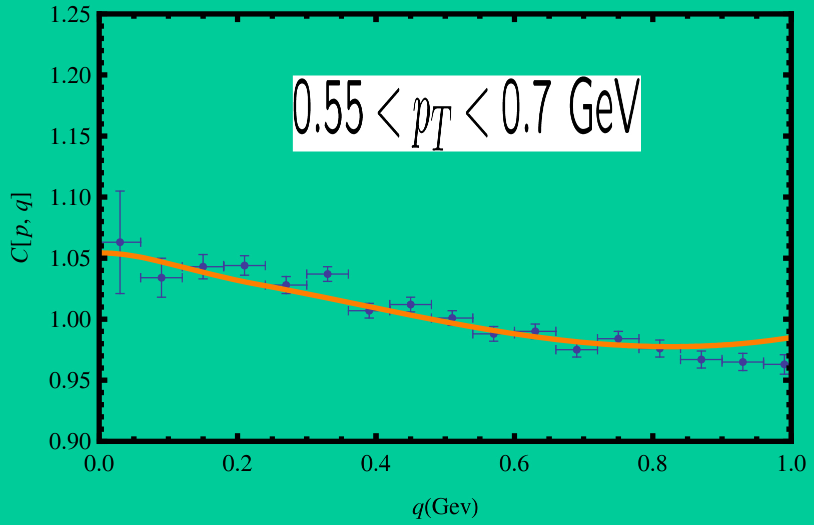


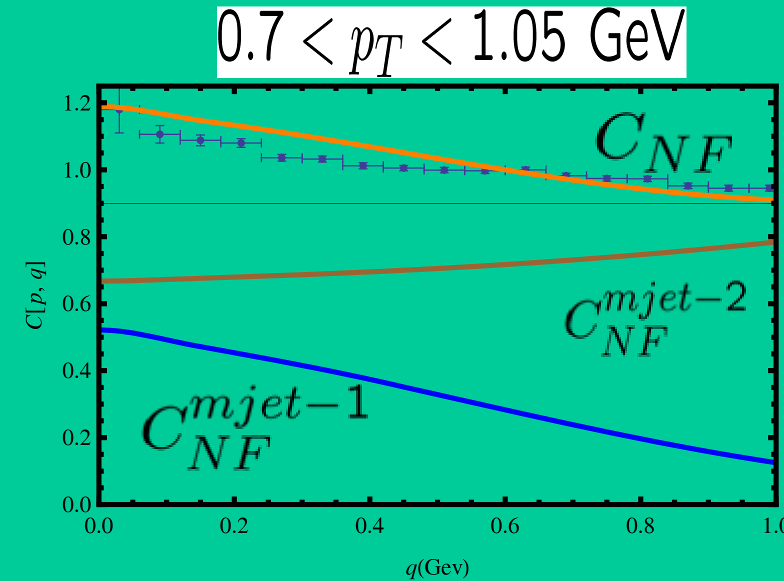


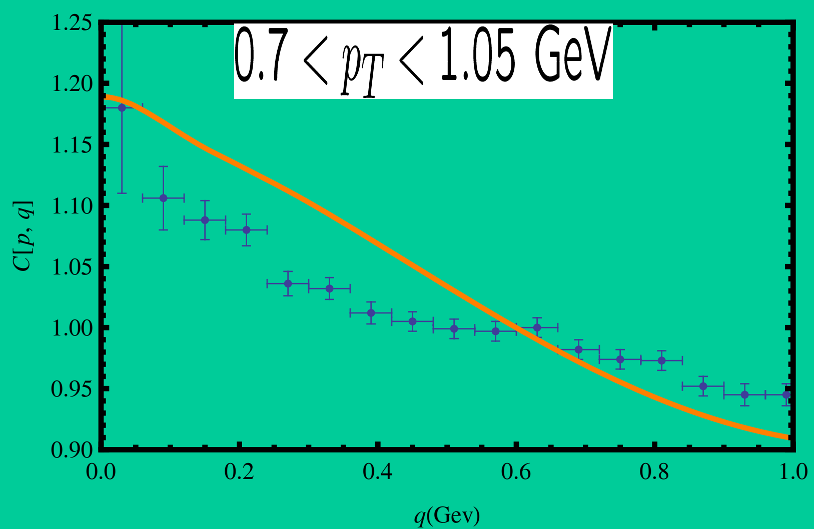


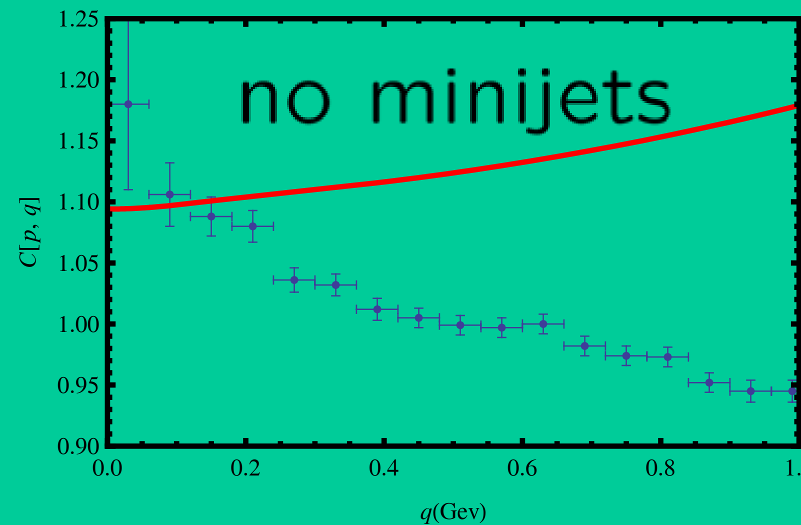
Data: PHOJET (ALICE paper), $N \geq 12$

$N = 17$, $T_T = \alpha = 0.75$ GeV









Data: PHOJET (ALICE paper), $N \geq 12$

Conclusion

- The simple model of "non-femtoscopic" correlations is proposed. The model takes into account correlations induced by conservation laws as well as correlations induced by minijets.
- The simplest approximation within the model results in reasonable description of the PHOJET event generator correlation baseline.
- The model description of "non-femtoscopic" correlations at low p_T (say, below 0.4 GeV) is not very good because one can hardly expect that minijets contribute noticeably to the particle momentum spectra there. Work to describe "non-femtoscopic" correlations in such a low p_T region is in progress.